

## ENGINEERED CRACK-RESISTANT PAPER AND BOARD

5

### BACKGROUND OF THE INVENTION

10

The present invention relates to an engineered crack-resistant paper or board, as well to a process of producing the paper and/or board. More specifically, the present invention relates to a crack-resistant, flaw-carrying paper and/or board that will have excellent runability.

15

Paper or board being produced with crack resistance, crack retardation, or fracture impedance is a growing requirement for many board or paper coated laminate structures. The structures are formed into various end uses such as containers, board, packaging, ovenable materials, coated paper, and the like. In particular, it is an objective to produce a tougher paper or paperboard.

20

There does exist prior patents which disclose various coating layers on base sheets. None are directed to impregnation in geometrical formation.

25

U.S. Patent No. 2,515,340 addresses the deposition of a polymer layer over an entire web. The objective of the patent is to make paper and paperboard resistant to wet rubbing and to the coloring of coated paper and paperboard in various selected colors.

30

U.S. Patent Nos. 5,004,643; 5,209,964; 5,418,051 and 5,876,792 relate to flexible porous webs which contain an internal coating of a silicone polymer composition. The patents discuss the use of pressurized impregnation methods. These patents focus on process related issues and deal with the "heavy saturation or impregnation with a polymer material" within textile, woven type configurations. They concentrate on encapsulating fibers used for forming webs. They do not discuss or suggest improvements in toughness, or mechanical performance of a cellulose fiber network web. The patents disclose rod-like fibers rather than tube-like fibers, on non-woven networks which are the focus of the underlying invention.

35

On the other hand, it is an objective of the invention to engineer paper and/or board capable of providing superior crack resistance or crack retardation mechanisms, thereby enhancing the product's fracture toughness and structural integrity. More particularly, geometric formations in the form of a thin discontinuous thermoplastic or thermosetting polymer film that penetrates a cellulose fiber network to provide islands that serves as a mechanism for crack retardation and fracture impedance.

It is a further objective of the invention to improve the overall mechanical performance of the paper or paperboard, thus impregnated.

It is another objective of the present invention to produce paper and/or board grades with improved runability and with the minimization or elimination of web failures which arise from the presence of defects in paper and the propagation of cracks.

**SUMMARY OF THE INVENTION**

According to one embodiment of the instant invention,  
a thin thermoplastic or thermosetting polymer is deposited onto  
a cellulose fiber network in geometrical formations. The polymer  
penetrates the cellulose fiber network web to provide islands  
that serve as a mechanism for crack retardation. The polymer  
deposition is applied after the web is formed, i.e., in the dry  
section.

The polymer is laid onto a base sheet in such a way  
that it forms a discontinuous impregnated film. The polymer  
penetrates into the base sheet or web to form a uniform paper or  
board surface to which a subsequent coating may be applied. The  
coated paper or board can then be printed upon.

**BRIEF DESCRIPTION OF THE DRAWINGS**

**FIGURE 1** is a template used to deposit a polymer material in a geometric pattern on a base sheet; and

**FIGURE 2** is an alternate embodiment of a template used to deposit a polymer material in a geometric pattern on a base sheet.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

There is disclosed, as a preferred embodiment of the invention, a crack-resistant paper and/or board that has an engineered thin discontinuous thermoplastic or thermosetting polymer material in specific geometric formations impregnated into a cellulose fiber network to provide islands that will serve as a mechanism for crack retardation and fracture impedance. The polymer deposition is applied after the web is formed, i.e., in the dry section. The applied polymer penetrates into the web so as to ultimately form a uniform paper surface to which a subsequent distinct polymer, or other coating may then be applied. The coated paper can then be printed upon. Thus, the invention focuses on crack-resistant base sheets produced through polymer deposition and impregnation, in geometric formations.

The impregnated polymer is formed in different geometries to reduce weight and maximize crack resistance efficiency. The base sheet thus formed may then be coated, printed upon and used for various or desired end uses.

Specifically desired is a tougher paper or board which has improved overall mechanical performance. The thin discontinuous thermoplastic or thermosetting polymer is applied in various geometrical formations such as in thin stripes, equidistant circles, and/or diamond shape formations. Other patterns are also within the contemplation of the invention. A very thin layer of the thermoplastic or thermosetting polymer is deposited, no more than 5% of the basis weight of the paper, to the surface of the paper after it has been formed. The polymer penetrates

into the paper or board in these geometrical formations before an additional coating can be applied. The resultant product can be wound on rolls.

A circular geometrical pattern as depicted in the template of Figure 1 is one preferred pattern. Specifically, a template is placed on top of a sheet of paper or board and secured in position. A liquid polymeric material is drawn over the template from a well using a brush, scraper, or the like. Accordingly the material will be deposited on the paper or board only at the position of the openings in the template and allowed to dry to provide a discontinuous impregnated film that gives strength to the paper or board.

Two principally distinct advantages may accrue from two different geometries as outlined in the cases below.

One example of a circular template format has 3mm diameter circles positioned 15 mm apart (center-to-center) to cover the entire sheet. The discontinuous circular reinforcement provides islands that serve as crack arresters or crack retarding mechanisms. Subsequently, the resulting reinforced base sheet possesses an appreciably higher fracture toughness, in both the MD and CD directions. The properties are presented in the table below.

Table 1: Results for the non-calendered polymer-impregnated (0.28% solids) base sheets

Sample	Direction	Basis weight (g/m <sup>2</sup> )	Caliper (mm)	Fracture toughness (J.m/kg)	% Increase in fracture toughness
Control	MD	42.9	0.104	21.1	
(No polymer)	CD	42.9	0.104	4.25	
0.28% solids	MD	41.9	0.108	26.9	27
	CD	41.9	0.108	12	182

Table 2: Results for the calendered polymer impregnated  
(1% solids) base sheets

Sample	Direction	Basis weight (g/m <sup>2</sup> )	Caliper (mm)	Fracture toughness (J.m/kg)	% Increase in fracture toughness
Control (calendered to 556 pli)	MD	42.5	0.063	14	
	CD	41.5	0.063	6.11	
1% solids (calendered to 556 pli)	MD	40.5	0.067	23.1	65
	CD	40.5	0.067	8.4	37

The other mechanical properties (tensile strength, elasticity modulus, stretch to break) experience no change between the control and the polymer-impregnated cases (calendered or not), thereby confirming the initial hypothesis that the polymer circular island serve as mechanisms of crack retardation while maintaining the structural integrity of the sheet.

Figure 2 depicts a rectangular template format: The polymer is applied similarly to what is discussed above along 2mm-wide stripes spanning the length of the sheet. A base sheet thus impregnated provides superior ductility in the MD direction and improved fracture toughness in the CD direction (with respect to the control - see above). The values are as follows:

Sample	Ductility - MD (J/g)	Fracture toughness - CD (J.m/kg)
0.28% solids	+42%	+250%
1% solids	+31%	+117%

Again the remaining mechanical properties (tensile strength, stretch, stiffness and elasticity modulus) exhibit no discernible change with respect to the control.

Templates are only one mechanism of depositing the thermoplastic or thermosetting materials onto the board or paper in geometrical formations. Any other mechanism for such is within the scope of the invention.

5           Materials such as diene-based rubbers which can be produced by emulsion polymerization, namely poly-butadiene, acrylonitrile-butadiene, ethylene vinyl acetate-butadiene and styrene-butadiene are all suitable polymers for the thin discontinuous thermoplastic polymer material. In addition, other  
10       polymers such as latex blends, copolyesters such as polyhydroxybutyrate and butanoate or cellulose acetate butyrate are also envisioned for the material. Further, it is possible to use various acrylics or polyesters including liquid crystalline polymers for the impregnation material.

Up until the invention described herein, there have been no processes for depositing and impregnating a thin discontinuous thermoplastic or thermosetting material into a dry cellulose fiber network web to serve as toughness and stiffness enhancers with the objective of producing a paper or board grade with trouble free runability. This technique improves runability and minimizes or eliminates web failures arising from the presence of defects in paper and the propagation of cracks.

20           The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof, and accordingly, reference should be made to the  
25       appended claims, rather than to the limits of the foregoing specification, as indicating the scope of the invention.